Lecture Module - Sensors

ME3023 - Measurements in Mechanical Systems

Mechanical Engineering

Tennessee Technological University

Module 4 - Sensors

Module 4 - Sensors

- Topic 1 - Introduction and Overview
- Topic 2 - IC and MEMS based Sensors

Introduction and Overview
IC and MEMS based Sensors

Analog and Digital Sensors
Example 1: Distance or Range
Example 2: Rotation
Example 3: Orientation

Topic 1 - Introduction and Overview

- Analog and Digital Sensors

- Example 1: Distance or Range

- Example 2: Rotation

- Example 3: Orientation

Introduction and Overview
IC and MEMS based Sensors

Analog and Digital Sensors
Example 1: Distance or Range
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Analog and Digital Sensors

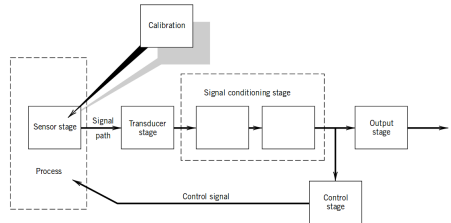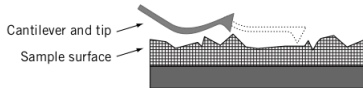a sensor, a physical element that employs some natural phenomenon... ...to sense the variable being measured

Cantilever and tip →
Sample surface →

Figure 1.5 Components of a general measurement system.

Introduction and Overview
IC and MEMS based Sensors

Analog and Digital Sensors
Example 1: Distance or Range
Example 2: Rotation
Example 3: Orientation

Analog and Digital Sensors

Sensors are typically classified as either **analog** or **digital** based on the type of signal that is output from the sensor.

However, this can be a misleading term. Many digital sensors operate based on analog circuit principles but require a digital circuit or MCU to operate or comminicate.

Analog	Digital	Both?

Introduction and Overview
IC and MEMS based Sensors

Analog and Digital Sensors
Example 1: Distance or Range
Example 2: Rotation
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Analog and Digital Sensors

Other Classifications:

- Contact vs Non-Contact
- Programmable (Configurable) vs Non-Programmable
- By Measured Variable

Introduction and Overview
IC and MEMS based Sensors

Analog and Digital Sensors
Example 1: Distance or Range
Example 2: Rotation
Example 3: Orientation

Example 1: Distance or Range

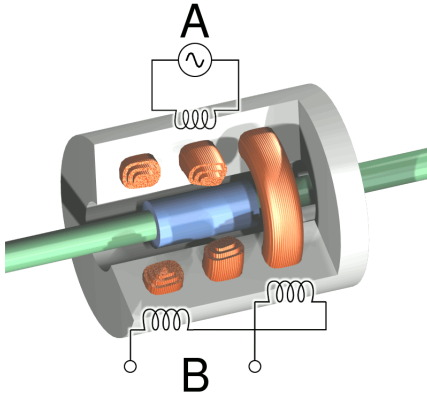**Thought Exercise:** How do we measure distance (aka range)?

- What variable or quantity is used to describe distance?
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- What type of sensor is used to measure this?
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Introduction and Overview
IC and MEMS based Sensors

Analog and Digital Sensors
Example 1: Distance or Range
Example 2: Rotation
Example 3: Orientation

Example 1: Distance or Range
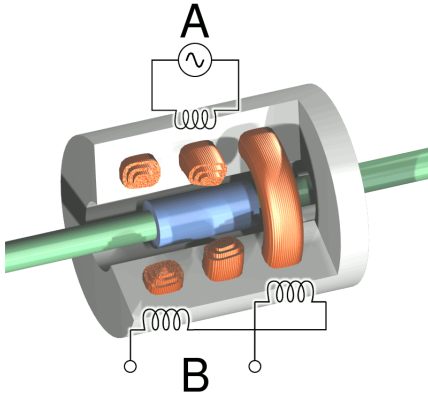
LVDTs with NI
LVDT Animation

Introduction and Overview
IC and MEMS based Sensors

Analog and Digital Sensors
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Example 1: Distance or Range

Introduction and Overview
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Analog and Digital Sensors
Example 1: Distance or Range
Example 2: Rotation
Example 3: Orientation

Example 3: Orientation

- What applications require this type of sensor?

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Introduction and Overview
IC and MEMS based Sensors

Analog and Digital Sensors
Example 1: Distance or Range
Example 2: Rotation
Example 3: Orientation

Example 3: Orientation

- How does this type of sensor work?

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Introduction and Overview
IC and MEMS based Sensors

Analog and Digital Sensors
Example 1: Distance or Range
Example 2: Rotation
Example 3: Orientation

Example 2: Rotation

Thought Exercise: How do we measure rotation?

- What variable or quantity is used to describe rotation?
  - ●
  - ●
  - ●

- What type of sensor is used to measure this?
  - ●
  - ●
  - ●

Introduction and Overview
IC and MEMS based Sensors

Analog and Digital Sensors
Example 1: Distance or Range
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Example 2: Rotation

Rotational Potentiometer

Introduction and Overview
IC and MEMS based Sensors

Analog and Digital Sensors
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Example 3: Orientation

Example 2: Rotation

Absolute Encoder

Introduction and Overview
IC and MEMS based Sensors

Analog and Digital Sensors
Example 1: Distance or Range
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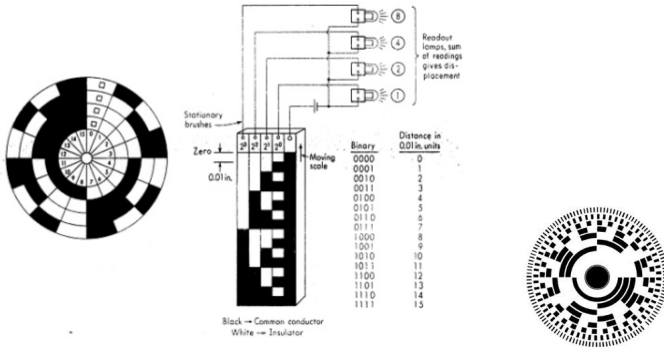
Incremental Encoder

2. Types of Rotary Encoder - Incremental

Construction of Incremental Rotary Encoder
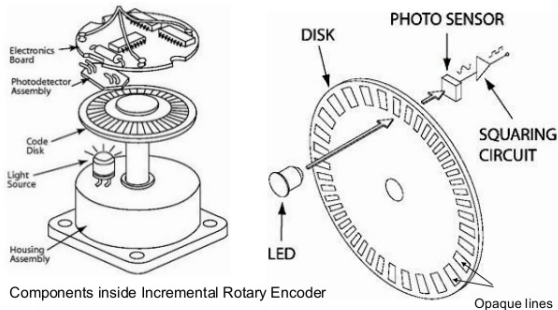
Components inside Incremental Rotary Encoder

Introduction and Overview
IC and MEMS based Sensors

Analog and Digital Sensors
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Example 2: Rotation

- What applications require this type of sensor?

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Introduction and Overview
IC and MEMS based Sensors

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Example 2: Rotation

- How does this type of sensor work?

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IC and MEMS based Sensors

Analog and Digital Sensors
Example 1: Distance or Range
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Example 3: Orientation

Thought Exercise: How do we measure orientation?

- What variable or quantity is used to describe orientation?
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- What type of sensor is used to measure this?
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Introduction and Overview
IC and MEMS based Sensors

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Example 3: Orientation

ADD EXAMPLE ORIENTATION SENSOR HERE

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Example 3: Orientation

- What applications require this type of sensor?

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IC and MEMS based Sensors

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Example 3: Orientation

- How does this type of sensor work?

Introduction and Overview
IC and MEMS based Sensors
Integrated Circuits
Micro Electro-Mechanical Devices
Example 1: Accelerometer
Example 2: Magnometer and Digital Compass

Topic 2 - IC and MEMS based Sensors

- Integrated Circuits

- Micro Electro-Mechanical Devices

- Example 1: Accelerometer

- Example 2: Magnometer and Digital Compass

Introduction and Overview
IC and MEMS based Sensors

Integrated Circuits
Micro Electro-Mechanical Devices
Example 1: Accelerometer
Example 2: Magnetometer and Digital Compass

Integrated Circuits

An integrated circuit (also known as an IC, a chip, or a microchip) is a set of electronic circuits on one small flat piece[a] of semiconductor material, usually silicon. Large numbers of miniaturized transistors and other electronic components are integrated together on the chip.

wikipedia: integrated circuit

Introduction and Overview
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Integrated Circuits
Micro Electro-Mechanical Devices
Example 1: Accelerometer
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Integrated Circuits

Actvitity: Group Brainstorming
List three applications or devices that use ICs and or IC based sensors.

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Integrated Circuits

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Micro Electro-Mechanical Devices

MEMS (micro-electromechanical systems) is the technology of microscopic devices incorporating both electronic and moving parts. MEMS are made up of components between 1 and 100 micrometres in size (i.e., 0.001 to 0.1 mm), and MEMS devices generally range in size from 20 micrometres to a millimetre (i.e., 0.02 to 1.0 mm), although components arranged in arrays (e.g., digital micromirror devices) can be more than 1000 mm2.[1] They usually consist of a central unit that processes data (an integrated circuit chip such as microprocessor) and several components that interact with the surroundings (such as microsensors)

Introduction and Overview
IC and MEMS based Sensors

Integrated Circuits
Micro Electro-Mechanical Devices
Example 1: Accelerometer
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Micro Electro-Mechanical Devices

Actvitity: Group Brainstorming List three sensors that are found on a high performance quadcopter or drone.

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Introduction and Overview
IC and MEMS based Sensors

Integrated Circuits
Micro Electro-Mechanical Devices
Example 1: Accelerometer
Example 2: Magnometer and Digital Compass

Example 1: Accelerometer

An accelerometer is a tool that measures proper acceleration, which is the acceleration of a body in its own instantaneous frame. Applications:

- Navigation Systems - Robotics - Aircraft - Missiles
- Personal Devices - Phones - Tablets
- Others:

Introduction and Overview
IC and MEMS based Sensors
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Example 1: Accelerometer

Thought Exercise: How do we measure acceleration?

Actvitity: Group Brainstorming
Explain one method for measuring acceleration of a body.

Introduction and Overview
IC and MEMS based Sensors

Integrated Circuits
Micro Electro-Mechanical Devices
Example 1: Accelerometer
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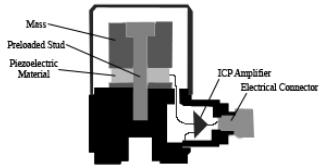
Example 1: Accelerometer

Mechanical Accelerometers Consist of a damped mass spring system and a sensing device.
Types of accelerometers:

- Seismometer or Seismograph
- piezoelectric - charge in material resulting from mechanical stress
- piezoresistive - change in resistance resulting from mechanical stress
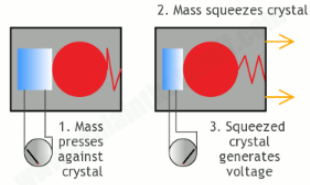- capacitive

Introduction and Overview
IC and MEMS based Sensors

Integrated Circuits
Micro Electro-Mechanical Devices
Example 1: Accelerometer
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Example 1: Accelerometer

piezoelectric accelerometer

Introduction and Overview
IC and MEMS based Sensors

Integrated Circuits
Micro Electro-Mechanical Devices
Example 1: Accelerometer
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Example 1: Accelerometer

capacitive accelerometer

Introduction and Overview
IC and MEMS based Sensors

Integrated Circuits
Micro Electro-Mechanical Devices
Example 1: Accelerometer
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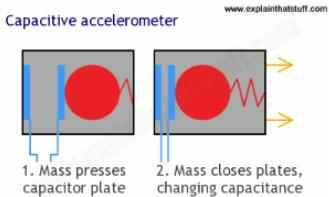
Example 2: Magnometer and Digital Compass

Thought Exercise: How do we measure orientation?

- What variable or quantity is used to describe motion?
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- What type of sensor is used to measure this?
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IC and MEMS based Sensors

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Micro Electro-Mechanical Devices
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Example 2: Magnometer and Digital Compass

- What applications require this type of sensor?

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IC and MEMS based Sensors

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Example 2: Magnometer and Digital Compass

A magnetometer is a device that measures magnetic field or magnetic dipole moment. Different types of magnetometers measure the direction, strength, or relative change of a magnetic field at a particular location. A compass is one such device, one that measures the direction of an ambient magnetic field, in this case, the Earth's magnetic field. Other magnetometers measure the magnetic dipole moment of a magnetic material such as a ferromagnet, for example by recording the effect of this magnetic dipole on the induced current in a coil.

wikipedia: magnetometer